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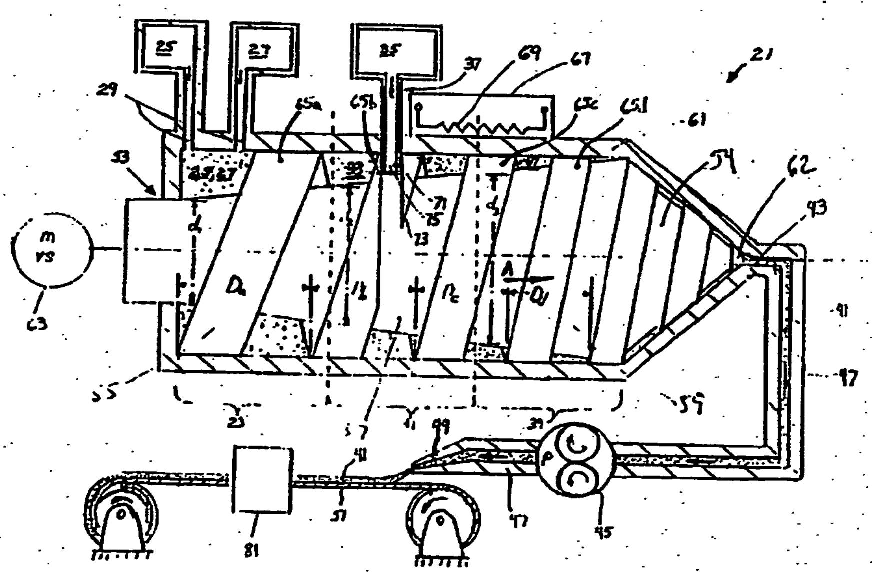

(57) Abstract

An apparatus (21) for continuous intimate mixing of materials for forming a cathode of a battery includes a blending portion (23), in which an active cathodic material (25) and a conductive filler material (27) are blended together. The blended active cathodic material (25) and conductive filler material (27) are mixed, in a mixing portion (31), with an electrolyte material (35) such that intimate mixing between the active cathodic material (25), the conductive filler material (27), and the electrolyte material (35) occurs. The mixture of active cathodic material (25), conductive filler material (27), and electrolyte material (35) is pressurized to a constant pressure at the outlet (43) of the apparatus.

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"CONTINUOUS SCREW MIXING AND EXTRUDING OF AN ELECTRODE PASTE"

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to an apparatus and method for mixing and extruding materials and, more particularly, to an apparatus and method for mixing and extruding a material for use as an electrode layer in a battery having a laminated electrode layer.

STATE OF THE ART

Workers in the battery art have begun to understand and recognize the advantages of batteries manufactured from laminates including solid polymer electrolytes and sheet-like anodes and cathodes over conventional liquid electrolyte batteries. The advantages include lower battery weights than batteries that employ liquid electrolytes, longer service life, relatively high power densities, relatively high specific energies, and the elimination of the danger associated with batteries containing spillable liquid electrolytes such as acids. Until recently, commercial use of such batteries was limited by, among other things, the inability of such batteries to operate effectively except at relatively high temperatures.

More recently, however, laminate batteries using polymer electrolytes have been developed which possess good performance characteristics at or below room temperature. For example, in U.S. Patent No. 4,925,751 to Shackle et al., the inventors note that, by minimizing cell impedance, the resulting cell may be used across a relatively broad range of temperatures, including temperatures below room temperature. The inventors minimize cell impedance through a combination of techniques, with particular attention being

given to the appropriate selection of materials used for forming the component layers of the cell, by the selection of optimal layer thicknesses for each of the component layers, and by the use of manufacturing techniques which minimize impedance across the interfaces between layers. To date, only relatively small-scale, largely experimental production of such batteries has occurred.

With the advent of commercially practical laminate batteries using polymer electrolytes arises the need for production of such batteries on a large scale. Apparatus and methods for large-scale production must permit use of appropriate materials, ensure optimal thickness of component layers, and otherwise use manufacturing techniques which minimize impedance at layer interfaces.

In the experimental production of the above-discussed batteries, the materials for forming a cathode layer of the laminate may be mixed in batches in a chamber, and with a device such as a double-planetary mixer, by a process that has proven satisfactory for limited production. The cathode material is formed from a mixture of active cathodic material (usually a V_6O_{13} or V_3O_8 material), a conductive filler material (usually carbon particles), and an ionically conductive electrolyte material. The mixture of active cathodic material, conductive filler material, and electrolyte material is heated in the chamber to a temperature sufficient to melt materials comprising the electrolyte material so that they can be intimately mixed with the cathodic material and the conductive filler material. Generally, it is necessary to heat the mixture to a temperature of approximately 85 °C. After mixing, the mixer apparatus is removed from the chamber, and a plunger apparatus compresses the mixed material through an orifice in the chamber and to a metering pump, which then transports the mixture to an extruder through which it is extruded onto an application site, usually a substrate upon which the cathode layer is coated.

SUMMARY OF THE PRESENT INVENTION

The present invention, generally speaking, provides an apparatus and a method for continuous production of cathode material for being coated in a layer on a substrate.

In accordance with one aspect of the present invention, an apparatus for the production of cathode material is disclosed. The apparatus includes means for mixing an active cathodic material and a conductive filler material with an electrolyte material such that intimate mixing occurs between the active cathodic material, the conductive filler material, and the electrolyte material and such that a homogeneous mixture is formed. The apparatus further includes means for pressurizing the mixed active cathodic material, conductive filler material, and electrolyte material to a constant outlet pressure. The mixing means and the pressurizing means are defined by respective sections of a common member for the continuous intimate mixture and pressurization of active cathodic material, conductive filler material, and electrolyte material.

In accordance with a further aspect of the present invention, the mixing means and the pressurizing means are arranged sequentially in an advancing direction of the apparatus.

In accordance with a further aspect of the present invention, the common member comprises a screw disposed in a barrel.

In accordance with still another aspect of the present invention, a method for continuous intimate mixture and pressurization of cathode material is disclosed. An active cathodic material and a conductive filler material are mixed with an electrolyte material such that intimate mixing and homogenization occurs between the active cathodic material, the conductive filler material, and the electrolyte material. The mixed active cathodic material, conductive filler

material, and electrolyte material are pressurized to a constant outlet pressure. The mixing and pressurizing steps occur continuously and simultaneously.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be further understood with reference to the following description in conjunction with the appended drawings, wherein like elements are provided with the same reference numerals. In the drawings:

Figure 1 is a schematic view of a continuous screw mixer according to a first embodiment of the present invention;

Figure 2 is a schematic view of a continuous screw mixer according to a second embodiment of the present invention;

Figure 3 is a schematic view of a screw for use with a continuous screw mixer according to a third embodiment of the present invention;

Figure 4 is a schematic view of a screw for use with a continuous screw mixer according to a fourth embodiment of the present invention;

Figure 5 is a schematic view of a screw for use with a continuous screw mixer according to a fifth embodiment of the present invention;

Figure 6 is a schematic view of a screw for use with a continuous screw mixer according to a sixth embodiment of the present invention;

Figure 7 is a schematic view of a screw for use with a continuous screw mixer according to a seventh embodiment of the present invention; and

Figure 8 is a block diagram of a thickness control apparatus according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the present invention, it has been discovered that the above-described batch production systems have several shortcomings. For instance, complete top-to-bottom mixing of the contents of the chamber may not be accomplished. In such a mixing process, many carbon particles (the micro-structure of which particles is filamentary) tend to be excessively broken and, therefore, shortened due to over-mixing of particular volumes of the material in the chamber by the double-planetary mixer. The shortened filamentary carbon particles tend to create high impedance paths in the cathode material, thereby reducing battery performance. Further, other volumes of the material in the chamber tend to be under-mixed, and excessively large carbon particles remain in the cathode material. The excessively large carbon particles network together and prevent intercalation of anode ions into the cathode material during operation of the battery.

Further in accordance with the present invention, it has been discovered that the above-described batch production systems have the complication that the cathode material (which is formed from intimately mixed active cathodic material, conductive filler material, and electrolyte material) has a paste-like consistency, having a viscosity in the range of 1,000,000 centipoise, and must be pressurized by the plunger to an extremely high pressure, usually approximately 500 p.s.i., in order for a metering pump, usually a gear pump, to be able to transport the cathode material at a desired feed rate. The pressures necessary for transport of the mixed material out of the mixing chamber to a substrate can require complex hydraulic or pneumatic equipment.

Still further in accordance with the present invention, it has been discovered that the above-described batch production systems have the complication that if materials are added in improper quantities or over-mixed, because the material is mixed in a batch, the entire batch is usually lost. It is presently recognized that cathode material such as described above has a shelf-life of approximately one day. Typically, production of a batch requires one day. Accordingly, if the batch is lost, the production for an entire day is lost.

As shown in Figure 1, an apparatus 21 for continuous intimate mixing and homogenization and for continuous pressurization of cathode materials includes a zone or portion 23 for, primarily, blending (hereinafter referred to as the blending portion) together an active cathodic material 25 with a conductive filler material 27. The active cathodic material 25 and the conductive filler material 27 are fed to the apparatus through one or more inlets 29. The apparatus 21 further includes a zone or portion 31 for, primarily, mixing (hereinafter referred to as the mixing portion) a blend 33 comprising the previously-fed active cathodic material 25 and conductive filler material 27 with an electrolyte material 35 such that intimate mixing occurs between the blend and the electrolyte material. The electrolyte material 35 is fed to the mixing portion 31 through a secondary inlet 37.

The apparatus 21 still further includes a zone or portion 39 for, primarily, pressurizing (hereinafter referred to as the pressurizing portion) the mixture of cathode material 41 comprising the blend 33 and the electrolyte material 35 to a constant pressure at the outlet 43 of the apparatus. The blending portion 23, the mixing portion 31, and the pressurizing portion 39 are sequential in an advancing direction A (shown by an arrow) of the apparatus 21.

The cathode material 41 is formed from a homogenous mixture of active cathodic material 25 (usually a V_6O_{13} or V_3O_8 material), a conductive filler material 27 (usually carbon particles), and an ionically conductive electrolyte

material 35 that are intimately and homogeneously mixed. The term "intimately mixed", as used herein, refers to a condition of the cathode material 41 in which the active cathodic material 25 and the conductive filler material 27 are broken down together to form approximately equal particle sizes, preferably less than 1 micron to approximately 5 microns, and are compounded with the electrolyte material, which is preferably a liquid, which penetrates throughout the active cathodic material and the conductive filler material. The term "homogenized", as used herein, refers to a condition of the cathode material 41 in which uniform samples, in terms of percent (volume or mass) of active cathodic material 25, conductive filler material 27, and electrolyte material 29 are taken throughout the cathode material. U.S. Patent No. 4,830,939 and U.S. Patent No. 4,925,751 more fully describe preferred active cathodic materials 25, preferred conductive filler materials 27, preferred electrolyte materials 35, and are incorporated by reference to the extent that they disclose such materials.

While, strictly speaking, the functions of blending, mixing, and compressing are performed continuously in each of the integrated blending portion 23, mixing portion 31, and compressing portion 39, in order to identify particular portions of the apparatus 21 for the purpose of discussion, the portions are identified by the primary activity occurring therein in the overall operation of the apparatus. The function performed in the blending portion 23, for example, is primarily directed to blending or mixing the active cathodic material 25 and the conductive filler material 27. In the blending portion 23, much of the breaking down of the active cathodic material 25 and the conductive filler material 27 into similarly-sized particles occurs. The function performed in the mixing portion 31, is primarily directed to mixing the already blended or mixed active cathodic material 25 and the conductive filler material 27 with the electrolyte material 35 such that the electrolyte material compounds with the active cathodic material and the conductive filler material. The function performed in the pressurizing portion 39 is primarily directed to pressurizing the

mixture of active cathodic material 25, conductive filler material 27, and electrolyte material 35 to a sufficient pressure to exit the apparatus 21.

The cathode material 41 formed in the apparatus 21 is pumped, preferably by a metering pump, which is preferably a gear pump 45, through a conduit 47, through an extruder nozzle 49, and onto a substrate 51, which is usually a conductive web or strip of material, such as a copper or nickel web. As shown in Figure 2, however, it is also possible to directly extrude the cathode material 41 through the extruder nozzle 49 and onto the substrate 51 without using a metering pump. Use of a metering pump, however, permits greater control of flow of cathode material 41 to the substrate 51, as the rate at which cathode material is pumped to the substrate may be controlled by means including a thickness sensor 81 and a microprocessor, shown in Figure 8 and discussed further below.

The apparatus 21 preferably includes a screw 53, shown in Figure 1, for continuous mixing and compressing, the screw forming a common member defining the successive zones or portions 23, 31, and 39. Portions of the screw 53 are disposed in the blending portion 23, the mixing portion 31, and the pressurizing portion 39. As the active cathodic material 25, conductive filler material 27, and electrolyte material 35 are moved in an advancing direction A along the length of the screw 53, they are continuously mixed to form the cathode material 41 and compressed for further transport or extrusion beyond the apparatus 21. The screw may assume different configurations. In that regard, screws 53, 53A, 53B, 53C, 53D, and 53E are depicted in Figures 1-2, 3, 4, 5, 6, and 7, respectively.

The screw 53 is preferably formed as a single piece and no distinct boundaries define the portions of the screw in the different portions 23, 31, 39 of the apparatus 21. However, as shown in Figure 7, the screw 53E may be formed of interconnected segments in which a screw segment 55 is provided in

the blending portion 23, a screw segment 57 is provided in the mixing portion 31, and a screw segment 59 is provided in the compressing portion 39. The screw segments 55, 57, 59 may be interconnected by male and female members 55m, 57f, 57m, 59f. While no distinct boundaries define different screw segments 55, 57, and 59 in the single piece screws shown in Figures 1-6, portions of the screw 53 substantially corresponding to the distinct segments shown in Figure 7 are shown by dashed lines in Figures 3-6 for comparative purposes.

As shown in Figures 1 and 2, the screw 53 is rotated inside of a barrel 61 by a drive means, which preferably includes a variable speed electric motor 63, so that material is advanced in the advancing direction A. As shown in Figures 1-5 and 7, the screw section 55 of the blending portion 23 is preferably formed with a smaller minor diameter d_1 than the minor diameter d_2 of the screw section 57 of the mixing portion 31 or the minor diameter d_3 of the screw section 59 of the pressurizing portion 39 so that the apparatus 21 is self-feeding. A metering portion or forward end 54 of the screw 53, and its thread 65, is shaped with a narrowing minor diameter or with bores and grooves (not shown) to direct the cathode material 41 through an outlet 62 of the barrel. The cathode material 41 exiting the apparatus 21 is in a substantially homogenous state as a result of having been continuously sheared against the threads of the screw 53 and the walls of the barrel 61 during blending, intimate mixing, and pressurization.

In addition to preferably forming the screw 53 with minor diameters d_1, d_2, and d_3, taken at subsequent points in the advancing direction A, that increase to facilitate self-feeding of the apparatus 21, the apparatus is formed such that the volume through which the cathode material 41 passes in the advancing direction either remains constant or decreases to facilitate flow of the cathode material. The cathode material 41 (as well as the active cathodic material 25, the conductive filler material 27, and the electrolyte material 35 that

form the cathode material) is a "shearing-thinning" material, meaning that its viscosity decreases as the material is subjected to increasing shear stress. If a shearing-thinning material is compressed, the material becomes less viscous and flows better. If a shearing-thinning material is allowed to expand, however, flow substantially stops at the point of expansion.

To maintain flow of the shearing-thinning materials in the advancing direction A through the apparatus 21, the void volume between the thread 65 of the screw 53 and the barrel 61 is decreased or remains constant in the advancing direction A, thereby preventing the material being mixed and compressed from expanding and stopping flowing. Representative screw thread profiles in which the void volume between the thread 65 and the barrel 61 remains constant or decreases are shown in Figures 1-7. In Figures 1-5 and 7, the screws 53, 53A, 53B, 53C, and 53E, respectively, have minor diameters d_1, d_2, and d_3, taken at subsequent points in the advancing direction A, that increase in the advancing direction A to facilitate reduction of the void volume.

The axial flight distances D_a, D_b, . . ., D_n of successive turns 65a, 65b, . . ., 65n of the thread 65 of the screws 53 and 53B, shown in Figures 1-2 and 4, respectively, are progressively reduced, and the axial flight distances between successive turns of the threads of the screws 53A and 53E, shown in Figures 3 and 7, respectively, are maintained at a substantially constant distance, to provide a screw in which a void volume between the thread of the screw and a barrel is reduced in the advancing direction A. The axial flight distances D_a, D_b, . . ., D_n between successive turns 65a, 65b, . . ., 65n of the thread 65 of the screw 53C, shown in Figure 5, are progressively increased, to reduce the void volume between the thread of the screw and a barrel in the advancing direction A. The minor diameter d of the screw 53D, shown in Figure 6, is held substantially constant in the advancing direction A. Alternatively, the void volume may be reduced in the advancing direction A by progressively reducing the axial flight distances D_a, D_b, . . ., D_n of successive turns 65a, 65b, . . ., 65n

of the thread of the screw (not shown), or the void volume may be held constant in the advancing direction by holding the axial flight distances constant (not shown). It is understood that the foregoing descriptions of screw profiles are merely illustrative and not intended to encompass all possible combinations of screw profiles in which the screw is shaped such that the void volume between the thread of the screw and a barrel decreases or remains constant.

The continued shearing of the material being mixed and compressed in the apparatus 21 also ensures that all areas of the volume of material being mixed and compressed receive substantially the same amount of mixing. The lengths of the sections 55, 57, and 59 and the thread profile of the screw 53-53E are selected so that more or less blending, mixing, and compression can be accomplished for a particular desired result, and so that the mean sizes of particles of conductive filler material 27 are optimized.

As shown in Figure 1, the apparatus 21 is preferably provided with a means 67 for heating the material being mixed and compressed above the melting point of the electrolyte material 35. The heating means 67 preferably includes a resistance heating element 69 arranged around or adjacent to the barrel 61 of the apparatus 21, however, core heating elements (not shown) disposed in the screw 53 or in the barrel or other heating techniques may be used. Preferably, the heating means 67 is arranged to heat a portion of the apparatus 21 by the mixing section 57 of the screw 53. Further, the heating means 67 is preferably arranged to heat a portion of the apparatus 21 subsequent, in the advancing direction A, to the secondary inlet 37 through which the electrolyte material 35 is introduced.

In addition to selecting the axial flight distances D_a, D_b, . . ., D_n of successive turns 65a, 65b, . . ., 65n of the thread 65 of the screw 53 to ensure that the void volume between the thread and a barrel decreases or remains constant in the advancing direction of the screw, the axial flight distances are

also selected to optimize the residence time of the material being blended, mixed, and compressed in the apparatus 21 and in the particular portions 23, 31, 39 of the apparatus. For example, if the axial flight distances D_a, D_b, . . ., D_n remain the same, as shown in the screws 53A and 53E in Figures 3 and 7, respectively, and the minor diameter of the screw increases in the advancing direction A, then it follows that, because the void volume steadily decreases through each successive turn of the thread 65a, 65b, . . ., 65n, the material in the apparatus 21 is moved at a progressively faster rate for each rotation of the screw.

If the axial flight distances D_a, D_b, . . ., D_n are increased in the advancing direction A, as shown in the screw 53C in Figure 5, then there will be an even further decreased residence time of material in the advancing direction, and the material is moved past the portions of the screw 53 having the longer axial flight distances even more quickly. Conversely, if the axial flight distances are decreased, as shown in the screws 53, 53A, 53B, and 53D in Figures 1-2, 3, 4, and 6, respectively, the material will reside in the portions of the screw 53 having the shorter axial flight distances for more turns of the screw. For example, the axial flight distances D_a, D_b, . . ., D_n are selected such that the residence time of the material is sufficiently long in the portion of the apparatus 21 near the heating means 67 to melt the electrolyte material 35. Further, where the conductive filler material 27 includes carbon filaments, the axial flight distances D_a, D_b, . . ., D_n are selected to optimize the degree of breakage of the filaments.

While the turning of the screw 53-53E relative to the barrel 61 will generally cause the material being mixed and compressed to shear to a sufficient extent that all of the material is moved in the advancing direction A, it may, nonetheless, occur that some of the material becomes trapped or clogged in the thread 65. It is desirable to provide the apparatus 21 with some additional self-cleaning mechanism. One or more stationary pins 71, shown in Figures 1 and 2, may be provided in the barrel 61 to extend substantially to the minor

diameter d of the screw 53 to clean out the thread 65. The screw 53 is further formed with a circumferential groove or break 73, i.e., a cut flight, through the thread 65 in a location on the screw corresponding to the location on the barrel of each stationary pin 71 so that the screw is able to rotate without interference from the stationary pin. Preferably, at least one stationary pin 71 is hollow and forms a portion of the secondary inlet 37 and is provided with an opening such as a bore 75 for facilitating introduction of electrolyte material 35 into the blend 33 of active cathodic material 25 and conductive filler material 27. Sufficient space is provided between the end of the hollow pin 71 and the bottom of the groove or break 73 so that electrolyte material 35 is able to flow out of the bore 75 in the pin.

Another self-cleaning mechanism that may be used in conjunction with or independently of the stationary pin 71 is a secondary screw 77, shown in Figure 2. The secondary screw 77 is formed with thread 79 for intermeshing with the thread 65 of the primary screw 53 to continually clean out the thread as the two screws rotate side by side. The foregoing self-cleaning mechanisms, i.e., the stationary pin 71 and the secondary screw 77, further facilitate intimate mixing of the components of the cathode material 41 by causing additional shearing of the material.

As noted above, compressed cathode material 41 exits the pressurizing portion 39 of the apparatus 21 and is either extruded directly onto the substrate 51 or, preferably, flows through the outlet 43 of the apparatus and onto the gear pump 45 through the conduit 47. From the gear pump 45, the cathode material 41 flows through an extruder nozzle 49 and onto the substrate 51.

The amount of cathode material 41 that is extruded onto the substrate 51 may, from time to time, have to be modified to adjust the thickness of the cathode material on the substrate. As shown in schematic form in Figure

1, a thickness measuring apparatus 81 is provided to measure the thickness of the cathode material 41 on the substrate 51. As shown in the block diagram of Figure 8, the thickness measuring apparatus 81 provides a signal to a microprocessor 82 to indicate that too much or too little cathode material 41 is being applied to the substrate 51. The microprocessor provides a signal to the gear pump 45 to cause the gear pump to slow down or speed up to advance more or less cathode material 41 to the substrate 51, or provides a signal to the variable speed electric motor 63 that turns the screw 53 to cause the screw to turn more or less quickly to advance more or less cathode material to the gear pump or the substrate, or provides a signal to both the gear pump and the variable speed electric motor to cause them both to speed up or slow down.

In a method for continuous intimate mixing and pressurization of cathode material 41 formed from active cathodic material 25, conductive filler material 27, and electrolyte material 35, the active cathodic material and the conductive filler material are blended together so that they are thoroughly dispersed. The blended active cathodic material 25 and conductive filler material 27 form a blend 33 that is mixed with an electrolyte material 35 such that intimate mixing between the cathodic material, the conductive filler material, and the electrolyte material occurs. The mixed active cathodic material 25, conductive filler material 27, and electrolyte material 35 form cathode material that is pressurized to a constant pressure at an outlet 43 of a mixing and pressurizing apparatus 21. The pressurized cathode material 41 is transported through a conduit 47 by a metering pump such as a gear pump 45 and passes through an extruder nozzle 49 to a substrate 51. The extruded cathode material 41 is spread over the substrate 51 in a constant thickness layer. The thickness of the constant thickness layer is measured and monitored for consistency and extrusion rates of cathode material 41 are adjusted to maintain constant thickness by adjusting the rate at which the gear pump 45 transports the cathode material or by adjusting the rate at which the screw 53 turns to transport the material, or by adjusting both the rate at which the gear pump and the screw operate.

The foregoing has described the principles, preferred embodiments and modes of operation of the present invention. However, the invention should not be construed as limited to the particular embodiments discussed. Instead, the above-described embodiments should be regarded as illustrative rather than restrictive, and it should be appreciated that variations may be made in those embodiments by workers skilled in the art without departing from the scope of present invention as defined by the following claims.

WHAT IS CLAIMED IS:

1. An apparatus for the production of cathode material comprising:

means for mixing an active cathodic material and a conductive filler material with an electrolyte material such that intimate mixing occurs between the active cathodic material, the conductive filler material, and the electrolyte material and such that a homogenous mixture is formed;

means for pressurizing the mixed active cathodic material, conductive filler material, and electrolyte material to a constant outlet pressure; and

means for blending the active cathodic material and the conductive filler material prior to mixing with the electrolyte material,

the blending means, the mixing means and the pressurizing means being defined by respective sections of a common member, the common member including a screw disposed in a barrel, the respective sections of the common member defining the blending means, the mixing means, and the pressurizing means, and the blending means, the mixing means, and the pressurizing means being arranged sequentially in an advancing direction of the apparatus for the serially applied blending of active cathodic material and conductive filler material and subsequent intimate mixture and pressurization of active cathodic material, conductive filler material, and electrolyte material, lengths of flights and void volumes defined by the flights and a minor diameter of the screw and the barrel differing over the respective sections of the common member defining the blending means, the mixing means, and the pressurizing means to achieve desired blending, mixing, and pressurization conditions, respectively, and such that the void volumes are non-increasing in an advancing direction of the screw.

2. The apparatus of Claim 1 further comprising means for blending the active cathodic material and the conductive filler material prior to mixing with the electrolyte material.

3. The apparatus of Claim 1 wherein the mixing means and the pressurizing means are arranged sequentially in an advancing direction of the apparatus.

4. The apparatus of Claim 3 wherein the common member comprises a screw disposed in a barrel.

5. The apparatus of Claim 1 wherein the screw includes separate screw segments defining the mixing means and the pressurizing means.

6. The apparatus of Claim 1 wherein the screw has a thread in which void volumes of succeeding turns of the thread in an advancing direction of the apparatus are less than or equal to void volumes of preceding turns of the thread.

7. The apparatus of Claim 6 wherein the screw has a minor diameter that increases in an advancing direction of the apparatus.

8. The apparatus of Claim 7 wherein an axial flight distance between succeeding turns of the thread decreases.

9. The apparatus of Claim 7 wherein an axial flight distance between succeeding turns of the thread increases.

10. The apparatus of Claim 1 wherein the mixing means includes means for heating the active cathodic material, the conductive filler material, and the electrolyte material.

11. The apparatus of Claim 1 further comprising a metering pump for transporting mixed and pressurized active cathodic material, filler material, and electrolyte material at a desired rate through an extruder means for being extruded onto a substrate.

12. The apparatus of Claim 11 wherein the metering pump is a gear pump.

13. The apparatus of Claim 1 further comprising means for measuring an amount of extruded material on the substrate and adjusting the rate at which the screw provides pressurized active cathodic material, filler material, and electrolyte material to the metering pump.

14. The apparatus of Claim 1 further comprising a secondary screw for intermeshing with at least portions of the screw.

15. The apparatus of Claim 1 wherein the screw includes a thread and the apparatus further comprises means for cleaning the thread.

16. The apparatus of Claim 15 wherein a turn of the thread is interrupted by a circumferential break, and the means for cleaning the thread includes a projecting member mounted on the barrel of the screw, the projecting member being received in the circumferential break as the screw turns.

17. The apparatus of Claim 16 wherein the projecting member is formed with a bore for introducing electrolyte material into the active cathodic material and conductive filler material.

18. A method for forming a cathode material, comprising the steps of:

mixing an active cathodic material and a conductive filler material with an electrolyte material such that intimate mixing and homogenization occurs between the active cathodic material, the conductive filler material, and the electrolyte material; and

pressurizing the mixed active cathodic material, conductive filler material, and electrolyte material to a constant outlet pressure,

the mixing and pressurizing steps occurring continuously and simultaneously.

19. The method of Claim 18 further comprising the step of blending the active cathodic material and the conductive filler material prior to mixing with the electrolyte material.

20. The method of Claim 18 comprising the further step of transporting pressurized active cathodic material, filler material, and electrolyte material at a desired rate through an extruder means onto a substrate.

21. The method of Claim 20 comprising the further step of measuring an amount of extruded material on the substrate and adjusting the rate at which the pressurized active cathodic material, filler material, and electrolyte material are transported.

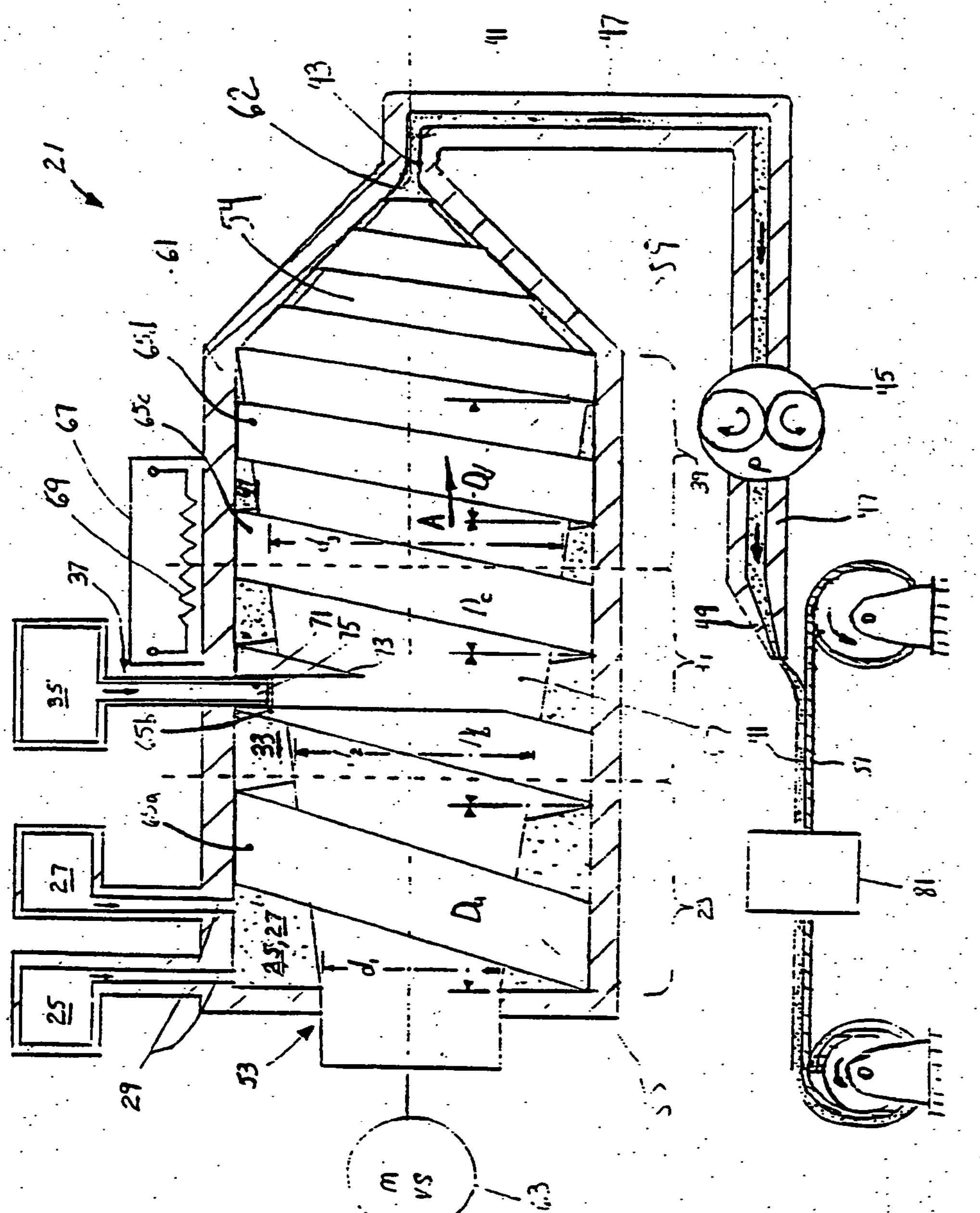
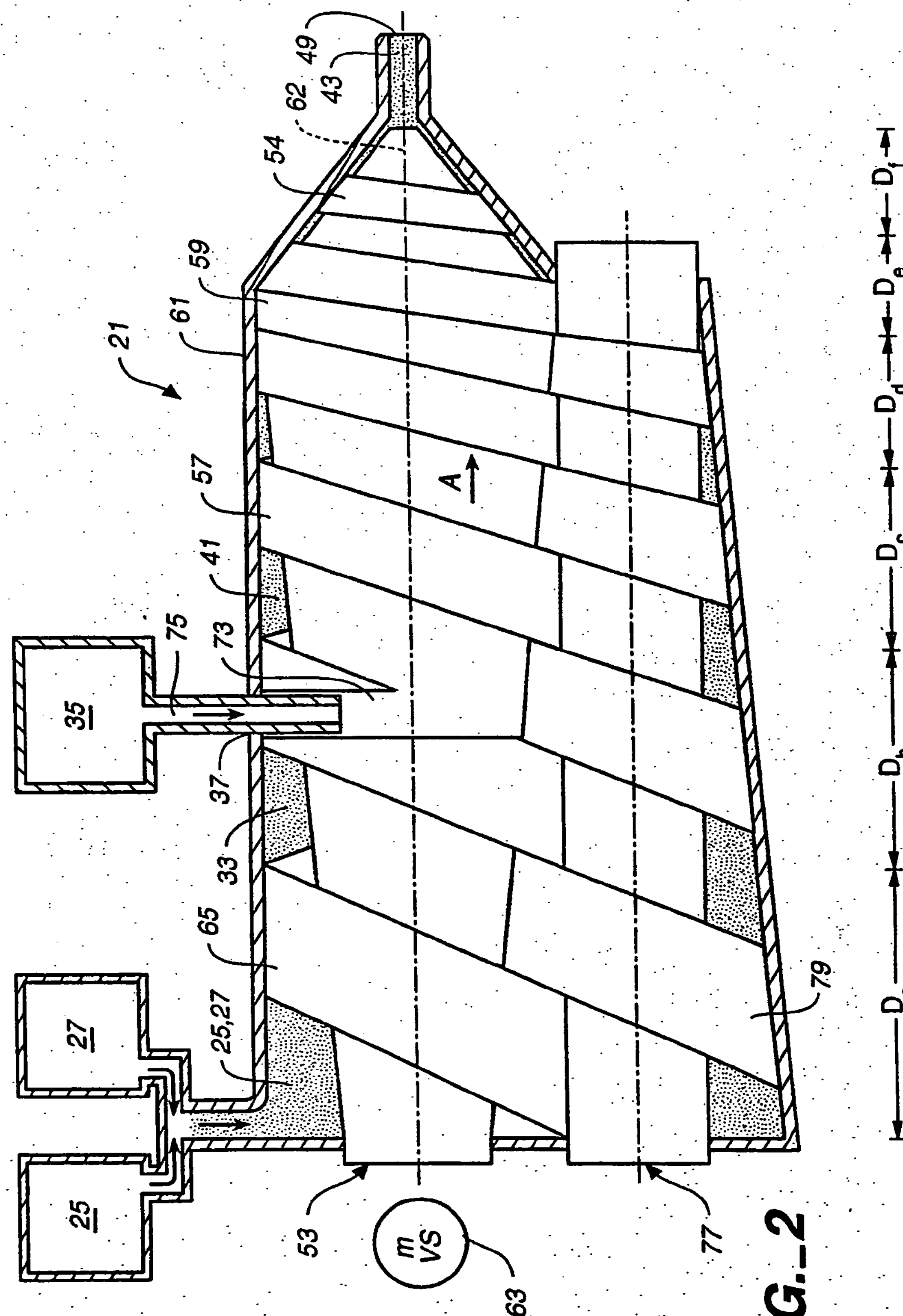


FIG. 1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77
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A
m
VS
D_a
D_b
D_c
D_d
D_e
D_f

FIG._2

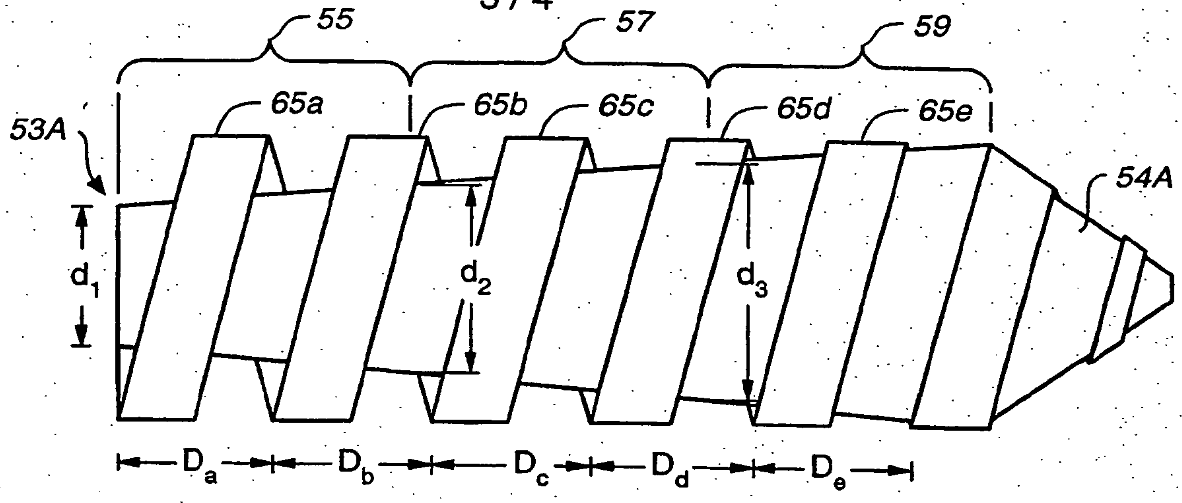

FIG._3

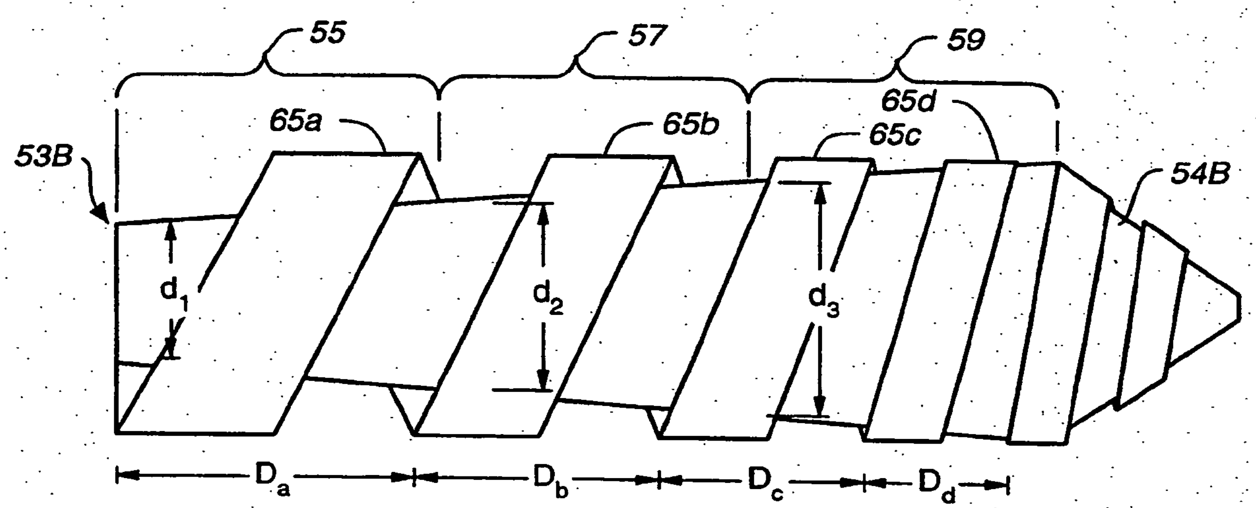

FIG._4

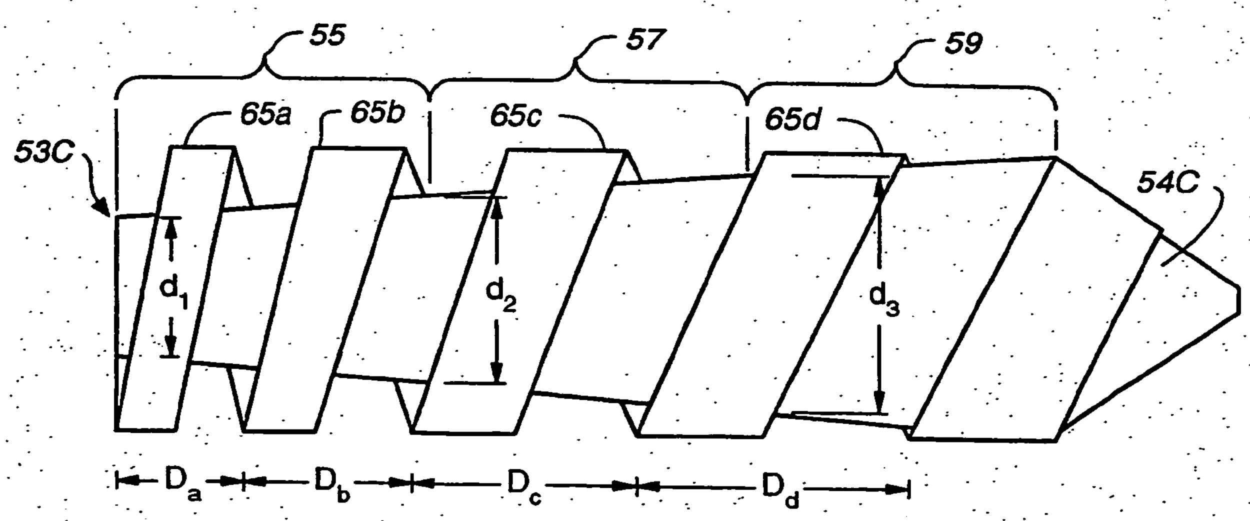

FIG._5

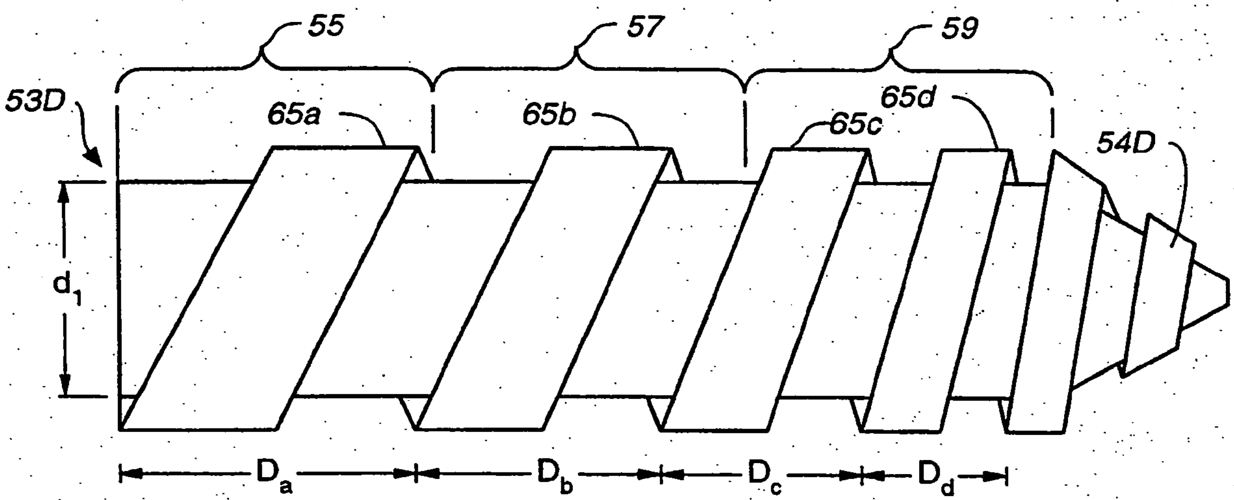

FIG._6

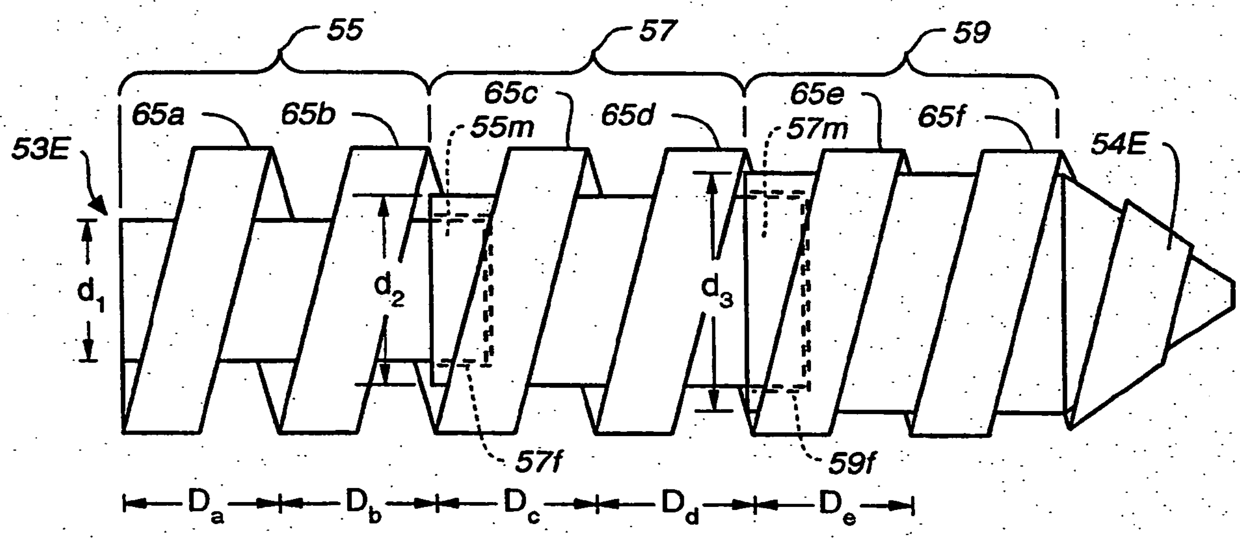

FIG._7

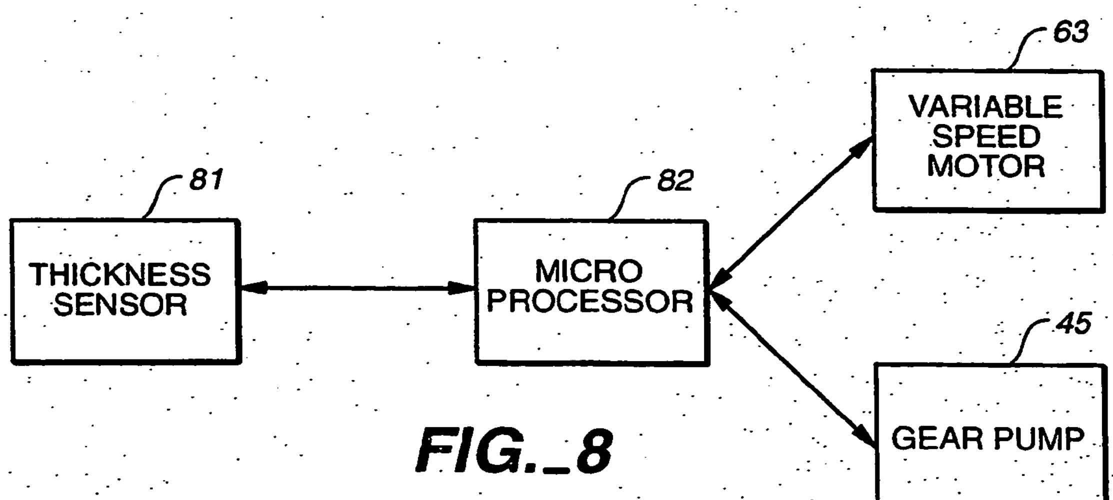

FIG._8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/00365

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01M 6/00; B29C 47/38
US CL :29/623.3; 264/105; 425/208
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 29/623.3; 264/105, 211.23; 425/131.1, 208

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US, A, 5,316,556 (MORRIS) 31 May 1994, figure 2; column 4, lines 25-57.	1-20
Y	US, A, 3,023,456 (PALFEY) 06 March 1962, column 3, lines 4-7; figure 1.	1, 2, 19
Y	US, A, 4,976,904 (BILHORN) 11 December 1990, figure 1; abstract; column 2, lines 27-35; column 3, lines 39-48; column 3, lines 62-65.	1, 2, 3, 4, 15-17
Y	US, A, 5,127,741 (CAPELLE ET AL) 07 July 1992, column 2, lines 26-28; column 2, lines 46-50.	5
Y	US, A, 3,577,494 (CHISHOLM ET AL) 04 May 1971, figures 2 and 4.	9

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 MARCH 1995	10 APR 1995

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/00365

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,156,790 (CUCCHISI ET AL) 20 October 1992, figure 1.	8
Y	US, A, 3,060,512 (MARTIN ET AL) 30 October 1962, figure 1; column 4, lines 40-68; column 4, line 74 to column 5, line 5.	10, 14
A	US, A, 4,384,837 (MURAI ET AL) 24 May 1983, figure 5.	
A	US, A, 4,648,827 (LAIMER ET AL) 10 March 1987, figure 2.	